

## CLAIMS:

1. A method for reducing preforming stresses within fibers in architectural preforms formed from high-strength polycrystalline ceramic fibers, the method comprising the steps of:

preparing an original sample composed of an architectural preform formed from an as-produced high-strength polycrystalline ceramic fiber type, where the architectural preform is at least one of a finite section of a continuous-length multi-fiber tow, a two-dimensional textile-formed fabric, and a three-dimensional textile-formed complex-shaped structure;

placing the original sample in a processing furnace under additional preforming stresses; and

thermally treating the original sample in the processing furnace at a processing temperature and a hold time in a processing gas having a composition, a pressure, and a flow rate;

wherein the composition of the ceramic fiber type, the total preforming stress state, the processing temperature and the hold time, and the composition, the pressure, and the flow rate are pre-selected to allow minimal loss in an average tensile strength of the fibers, to allow preforming stresses within the ceramic fibers created by the preparation and placement steps on the original sample to be reduced by creep-relaxation, and to allow the thermally treated sample to achieve a more technically advantageous preform shape.

2. The method as recited in claim 1, wherein the fiber composition, the processing temperature and the hold time, and the gas composition, the pressure, and

the flow rate are preselected to also allow atomic decomposition from the surface of each fiber and the in-situ growth of a layer on the surface of each fiber with a composition different than that of the bulk fiber.

3. A method for producing high-strength ceramic fibers and ceramic fiber architectural preforms with an in-situ grown coating on each fiber surface with a composition different than that of the bulk fiber, the method comprising the steps of:

preparing an original sample composed of an architectural preform formed from an as-produced high strength ceramic fiber type, where the architectural preform is at least one of a finite section of a continuous-length multi-fiber tow, a two-dimensional textile-formed fabric, and a three-dimensional textile-formed complex-shaped preform;

placing the original sample in a processing furnace; and

thermally treating the original sample in the processing furnace at a processing temperature and a hold time in a processing gas having a composition, a pressure, and a flow rate;

wherein the fiber composition, the processing temperature and the hold time, and the gas composition, the pressure, and the flow rate are preselected to allow atomic decomposition from the surface of each fiber, with minimal loss in an average tensile strength of the fibers within the thermally treated sample.

4. The method as recited in one of claims 1, 2, and 3, wherein the fiber composition is based on silicon carbide (SiC), the gas composition is based on a chemically inert composition, and the in-situ grown coating on each fiber surface has a carbon-rich composition.

5. The method as recited in claim 4, wherein the step of thermal treatment comprises processing the original sample in the processing furnace at a processing temperature between 1700°C and 1900°C for a processing hold-time of five hours or less in a high purity argon gas at a pressure between 1 and 40 atmospheres with a flow rate between zero and one cubic-foot/hr.

6. The method as recited in claim 1, wherein the fiber composition, the processing temperature and the hold time, and the gas composition, the pressure, and the flow rate are preselected to also allow the removal of boron from the bulk of each fiber within the treated sample.

7. The method as recited in claim 2, wherein the fiber composition, the processing temperature and the hold time, and the gas composition, the pressure, and the flow rate are preselected to also allow the removal of boron from the bulk of each fiber within the treated sample.

8. The method as recited in claim 3, wherein the fiber composition, the processing temperature and the hold time, and the gas composition, the pressure, and the flow rate are preselected to also allow the removal of boron from the bulk of each fiber within the treated sample.

9. A method for producing high-strength ceramic fibers and ceramic fiber architectural preforms with reduced boron in the bulk of each fiber, the method comprising the steps of:

preparing an original sample composed of an architectural preform formed from an as-produced high strength boron-containing ceramic fiber type, where the architectural preform is at least one of a finite section of a continuous-length multi-

fiber tow, a two-dimensional textile-formed fabric, and a three-dimensional textile-formed complex-shaped preform;

placing the original sample in a processing furnace; and

thermally treating the original sample in the processing furnace at a processing temperature and a hold time in a processing gas with a composition, a pressure, and a flow rate;

wherein the fiber composition, the processing temperature and the hold time, and the gas composition, the pressure, and the flow rate are preselected to allow the removal of boron from the bulk of each fiber, with minimal loss in an average tensile strength of the fibers within the treated sample.

10. The method as recited in one of claims 1, 2, 3, 6, 7, and 9; wherein the fiber composition is based on silicon carbide (SiC) with boron additives and the gas composition is based on a chemically inert composition.

11. The method as recited in claim 10, wherein the step of thermal treatment also allows an improved tensile creep resistance and an improved tensile rupture resistance of each fiber in the thermally treated sample.

12. The method as recited in claim 11, wherein the step of thermal treatment comprises processing the original sample in the processing furnace at a processing temperature between 1700°C and 1900°C for a processing hold-time of five hours or less in a high purity argon gas at a pressure between 1 and 40 atmospheres with a flow rate between zero and one cubic-foot/hr.

13. The method as recited in claim 12, wherein the step of thermal treatment comprises processing the original sample in the processing furnace at a processing

temperature of 1800°C for a processing hold-time of one hour at a pressure of 40 atmospheres with a flow rate of zero cubic-foot/hr.

14. A method for producing high-strength ceramic fibers and ceramic fiber architectural preforms with boron-containing surface coatings on each fiber, the method comprising the steps of:

preparing an original sample composed of an architectural preform formed from a high strength boron-containing ceramic fiber type, where the architectural preform is at least one of a finite section of a continuous-length multi-fiber tow, a two-dimensional textile-formed fabric, and a three-dimensional textile-formed complex-shaped preform;

placing the original sample in a processing furnace; and

thermally treating the original sample in the processing furnace at a processing temperature and a hold time in a processing gas having a composition, a pressure, and a flow rate;

wherein the processing temperature and the hold time, and the pressure, and the flow rate are preselected to allow the simultaneous removal of boron from each fiber and the in-situ growth of a coating with a boron-containing composition on each fiber surface, with minimal loss in an average tensile strength of the fibers within the thermally treated sample.

15. The method as recited in claim 14, wherein the fiber composition, the processing temperature and the hold time, and the gas composition, the pressure, and the flow rate are preselected to also allow preforming stresses within the ceramic fibers created by the preparation and placement steps on the original sample to be

reduced by creep-relaxation, thereby allowing the thermally treated sample to achieve a more technically advantageous preform shape.

16. The method as recited in one of claims 1, 6, 9, 14, and 15; wherein the fiber composition is based on silicon carbide (SiC) with boron additives and the gas composition is based on nitrogen.

17. The method as recited in claim 16; wherein the step of thermal treatment allows the in-situ growth of a coating on each fiber surface with a composition containing boron nitride (BN) and the properties of an improved tensile creep resistance and an improved tensile rupture resistance for each fiber in the thermally treated sample.

18. The method as recited in claim 17; wherein the step of thermal treatment comprises processing the original sample in the processing furnace at a processing temperature between 1700°C and 1900°C for a processing hold-time of five hours or less in a high purity nitrogen gas at a pressure between 1 and 40 atmospheres with a flow rate between zero and one cubic-foot/hr.

19. The method as recited in claim 18; wherein the step of thermal treatment comprises processing the original sample in the processing furnace at a processing temperature of 1800°C for a processing hold-time of one hour at a pressure of 40 atmospheres with a flow rate of zero cubic-foot/hr.

20. A method for producing a SiC fiber-reinforced composite material structure with improved properties, the method comprising the steps of:

preparing an original sample composed of an architectural preform formed from an as-produced high strength ceramic fiber type with a composition based on

silicon carbide (SiC) with boron additives, where the architectural preform is at least one of a finite section of a continuous-length multi-fiber tow, a two-dimensional textile-formed fabric, and a three-dimensional textile-formed complex-shaped preform;

placing the original sample in a processing furnace;

thermally treating the original sample in the processing furnace at a processing temperature between 1700°C and 1900°C for a processing hold-time of five hours or less in a composition of at least one of a high purity argon and a high purity nitrogen gas at a pressure between 1 and 40 atmospheres with a flow rate between zero and one cubic-foot/hr;

depositing a thin interphase coating on the surface of each fiber within the treated sample by chemical vapor infiltration; and

forming a matrix within the coated sample with at least one of a ceramic and a carbon-based composition, thereby producing a final sample comprising a SiC fiber-reinforced composite material structure with improved properties.

21. The method as recited in claim 20; wherein the matrix forming step comprises of at least one of chemical vapor infiltration, ceramic particulate infiltration, non-reactive liquid infiltration, reactive liquid infiltration, reactive vapor infiltration, and polymer liquid infiltration and pyrolysis.

22. The method as recited in claim 20; wherein the composition of the interphase fiber coating is based at least one of boron nitride and carbon, and the composition of the matrix is based on at least one of silicon carbide and silicon nitride.

23. The method as recited in claim 22; wherein the thermal treatment step on the original sample is performed under high purity nitrogen gas, the fiber coating composition is based on boron nitride, and the final sample comprises a SiC fiber-reinforced ceramic matrix composite structure with improved properties including ultimate tensile strength, intrinsic strength retention at high temperatures, rupture strength after matrix pre-cracking, and long-term oxidation resistance that are greater in comparison to same properties of final samples without the thermal treatment step.

24. The method as recited in claim 23, wherein the final sample comprises a SiC fiber-reinforced ceramic matrix composite structure with total fiber content greater than 20 volume percent.

25. The method as recited in claim 23, wherein the ceramic matrix is formed within the interphase-coated sample by chemical vapor infiltration, the residual porosity of the composite structure ranges from 10 to 40%, and the remaining open pores in the composite structure are filled by at least one of ceramic particulate infiltration, non-reactive metal melt infiltration, reactive metal melt infiltration, and polymer liquid infiltration and pyrolysis.

26. The method as recited in claim 23; wherein the ceramic matrix is formed within the interphase coated sample by at least one of a ceramic particulate infiltration and a polymer liquid infiltration and pyrolysis.

27. The method as recited in at least one of claims 25 and 26, wherein the ceramic matrix composition by chemical vapor infiltration is based on SiC, the ceramic particulate is based on SiC, the non-reactive and reactive metal composition



is based on silicon, and the composition of pyrolyzed polymer is based on at least one of SiC and silicon nitride.